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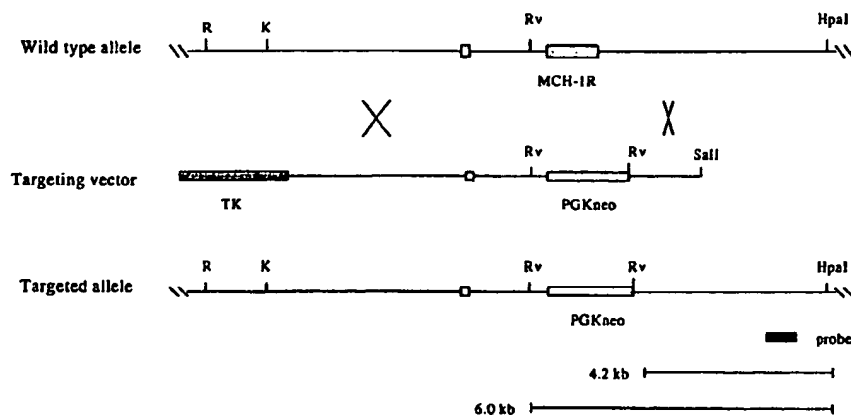
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(54) Title: MCH1R DEFICIENT MICE



(57) Abstract: The present invention features viable MCH1R deficient mice. MCH1R deficient mice contain an alteration in one or both MCH1R alleles that substantially reduces expression of a functional MCH1R from the altered allele. Preferably, MCH1R deficient mice are MCH1R ^{-/-} knockout mice.

WO 02/077168 A2

TITLE OF THE INVENTION
MCHIR DEFICIENT MICE

CROSS-REFERENCE TO RELATED APPLICATIONS

- 5 The present application claims priority to provisional application U.S. Serial No. 60/278,061, filed March 22, 2001, hereby incorporated by reference herein.

BACKGROUND OF THE INVENTION

- 10 The references cited in the present application are not admitted to be prior art to the claimed invention.

 Neuropeptides present in the hypothalamus play a major role in mediating the control of body weight. (Flier, *et al.*, 1998. *Cell*, 92, 437-440.) Melanin-concentrating hormone (MCH) is a cyclic 19-amino acid neuropeptide synthesized as part of a larger pre-prohormone precursor in the hypothalamus which
15 also encodes neuropeptides NEI and NGE. (Nahon, *et al.*, 1990. *Mol. Endocrinol.* 4, 632-637.) MCH was first identified in salmon pituitary, and in fish MCH affects melanin aggregation thus affecting skin pigmentation. In trout and in eels MCH has also been shown to be involved in stress induced or CRF-stimulated ACTH release. (Kawauchi, *et al.*, 1983. *Nature* 305, 321-323.)

- 20 In humans two genes encoding MCH have been identified that are expressed in the brain. (Breton, *et al.*, 1993. *Mol. Brain Res.* 18, 297-310.) In mammals MCH has been localized primarily to neuronal cell bodies of the hypothalamus which are implicated in the control of food intake, including perikarya of the lateral hypothalamus and zona inertia. (Knigge, *et al.*, 1996. *Peptides* 17, 1063-
25 1073.)

 Pharmacological and genetic evidence suggest that the primary mode of MCH action is to promote feeding (orexigenic). MCH mRNA is up regulated in fasted mice and rats and in the *ob/ob* mouse. (Qu, *et al.*, 1996. *Nature* 380, 243-247.) Injection of MCH centrally (ICV) stimulates food intake and MCH antagonizes the
30 hypophagic effects seen with α melanocyte stimulating hormone (α MSH). (Qu, *et al.*, 1996. *Nature* 380, 243-247.) MCH deficient mice are lean, hypophagic and have increased metabolic rate. (Shimada, *et al.*, 1998. *Nature* 396, 670-673.) Transgenic mice overexpressing MCH are hyperphagic and develop insulin resistance and mild obesity. (Ludwig, *et al.*, 2001. *J. Clin. Invest.* 107, 379-386.)

MCH action is not limited to modulation of food intake as effects on the hypothalamic-pituitary-axis have been reported. (Nahon, 1994. *Critical Rev. in Neurobiol.* 8, 221-262.) MCH can modulate stress-induced release of ACTH. (Nahon, 1994. *Critical Rev. in Neurobiol.* 8, 221-262.)

5 Several references describe a receptor that is indicated to bind MCH ("MCH1R"). (Chambers, *et al.*, 1999. *Nature* 400, 261-265, Saito, *et al.*, 1999. *Nature* 400, 265-269, Bächner, *et al.*, 1999. *FEBS Letters* 457:522-524, Shimomura, *et al.*, 1999. *Biochemical and Biophysical Research Communications* 261, 622-626.)

10 SUMMARY OF THE INVENTION

 The present invention features viable MCH1R deficient mice. MCH1R deficient mice contain an alteration in one or both MCH1R alleles that substantially reduces expression of a functional MCH1R from the altered allele. Preferably, MCH1R deficient mice are MCH1R $-/-$ knockout mice.

15 An alteration that "substantially reduces expression" of a functional MCH1R is either (1) an alteration that results in no active MCH1R being produced from the altered allele or (2) an alteration that results in a MCH1R deficient mouse having one or more phenotypes associated with an MCH1R $-/-$ knockout mouse, when the alteration is present in both alleles. Alterations substantially reducing expression
20 of a functional MCH1R include alterations that result in little or no MCH1R expression and alterations producing a MCH1R derivative which is expressed but contains little or no activity.

 Phenotypes associated with a MCH1R $-/-$ knockout mouse include: reduced fat mass, increased food consumption when mice are maintained on regular
25 chow, hyperactivity, neuroendocrine abnormalities, increased energy expenditure as measured by indirect calorimetry, reduced respiratory quotient as measured by indirect calorimetry, decreased sensitivity to diet-induced obesity, resistance to the orexigenic effects of intracerebroventricular administration of MCH and resistance to the anorectic effects of intracerebroventricular administration a peptide antagonist of
30 MCH1R.

 Thus, a first aspect of the present invention describes a MCH1R deficient mouse whose genome comprises an alteration in one or both MCH1R alleles. The alteration substantially reduces expression of a functional MCH1R from the altered allele.

Another aspect of the present invention describes a method of producing a MCH1R deficient mouse comprising an alteration of a MCH1R allele. The method comprises the steps of:

- 5 (a) altering a MCH1R allele in a mouse embryonic stem cell by homologous recombination with a transgene to produce an altered embryonic stem cell;
- (b) introducing the altered embryonic stem cell into a mouse blastocyst to produce an altered blastocyst;
- (c) introducing the altered blastocyst into a pseudopregnant mouse
10 to produce a pregnant mouse;
- (d) allowing the pregnant mouse to produce offspring; and
- (e) screening the offspring for the presence of an altered MCH1R allele to identify an MCH1R deficient mouse.

Another aspect of the present invention describes a method of
15 producing a MCH1R deficient mouse comprising an altered MCH1R in both alleles. The method comprises the steps of: (a) breeding two mice each comprising an alteration of the MCH1R in one allele to produce offspring; and (b) screening the offspring for the presence of an altered MCH1R in both alleles.

Another aspect of the present invention describes a method of
20 measuring the affect of a compound on a MCH1R deficient mouse. The method involves the steps of providing the compound to the MCH1R deficient mouse, and measuring one or more phenotypes associated with MCH1R activity.

Another aspect of the present invention describes a method of
25 screening for a compound to affect food intake, metabolism, stress, anxiety, fatigue, locomotor activity, circadian rhythm, or sleep. The method comprises identifying an MCH1R active compound able to modulate MCH1R activity using an *in vitro* assay; and measuring the ability of the MCH1R active compound on food intake, metabolism, stress, anxiety, fatigue, locomotor activity, circadian rhythm, or sleep.

Other features and advantages of the present invention are apparent
30 from the additional descriptions provided herein including the different examples. The provided examples illustrate different components and methodology useful in practicing the present invention. The examples do not limit the claimed invention. Based on the present disclosure the skilled artisan can identify and employ other components and methodology useful for practicing the present invention.

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BRIEF DESCRIPTION OF THE DRAWING

Figure 1. Strategy employed for disrupting the MCH1R gene. "TK" refers to a HSV-thymidine kinase gene. "PGKneo" refers to a neomycin resistance gene.

5 Figure 2. DEXA analysis of 5-7-month-old group-housed male and female MCH1R $+/+$ (white bars), MCH1R $+/-$ (hatched bars) and MCH1R $-/-$ (shaded bars; $n = 12-14$ per group) littermate mice. All P values are from comparisons between MCH1R $+/+$ and MCH1R $-/-$ littermates. $**P < 0.01$, $*P < 0.05$.

10 Figure 3. Metabolic rate of ~8-week-old individually-housed male MCH1R $+/+$ ($n = 10$; filled squares) and MCH1R $-/-$ ($n = 13$; open circles) littermates. From 10 PM to 5 AM, the MCH1R $-/-$ curve was significantly different ($P < 0.05$) from the MCH1R $+/+$ curve. The solid horizontal bar represents the dark phases of the study.

15 Figure 4. Respiratory quotient (RQ) of mice in Figure 3. The MCH1R $-/-$ curve was significantly different ($P < 0.01$) from the MCH1R $+/+$ curve for the entire light phase. The solid horizontal bar represents the dark phases of the study.

20 Figure 5. Cumulative body weight gains of female wild-type ($Mch1r^{+/+}$) and $Mch1r^{-/-}$ littermates maintained simultaneously on either a regular chow diet (RC) or a high fat diet (HF) for 7 weeks ($n = 9-12$ per group). All groups were weight matched and all mice were 6-8-weeks-old at the initiation of the study.

25 Figure 6. Cumulative food intake by mice in Figure 5 during the 7-week period ($n = 9-11$ per group). P values are from comparisons between chow and high fat groups of the same genotype (*) or between $Mch1r^{+/+}$ and $Mch1r^{-/-}$ littermates maintained on the same diet (**). $*P < 0.05$, $**P < 0.001$.

30 Figure 7. Effect of chronic MCH infusion on daily food intake. Male 11-13-week-old MCH1R $+/+$ (squares) and MCH1R $-/-$ (circles) littermates received chronic dorsal third ventricle infusions of either MCH (~12 nmole/mouse/day; filled symbols) or vehicle (open symbols) for 6 days ($n = 9-11$ per group). Mice were cannulated and implanted with osmotic pumps containing only vehicle on day -5. On day 0, original pumps were replaced with new pumps containing either vehicle or MCH dissolved in vehicle. Beginning on day 1, all mice were maintained on a moderate fat diet. From days 1 to 6, the MCH1R $+/+$, MCH-treatment curve was significantly different ($P < 0.005$) from the three other curves.

Figure 8. Effect of chronic MCH infusion on cumulative body weight gain. Body weights of mice in Figure 7 were measured daily and values from day -4 were used to calculate cumulative body weight gains. From days 1 to 6, the MCH1R +/+, MCH-treatment curve was significantly different ($P < 0.0001$) from the three other curves.

Figure 9. Effect of chronic MCH infusion on body composition. DEXA analysis of body composition was performed on mice in Figure 7 at the end of the 6-day chronic infusion period MCH1R +/+: vehicle, white bars; MCH, hatched bars; MCH1R -/-: vehicle, shaded bars; MCH, striped bars). P values are from comparisons between treatment groups of the same genotype (*) or between genotypes of the same treatment (**). * $P < 0.005$, ** $P < 0.01$.

DETAILED DESCRIPTION OF THE INVENTION

MCH1R deficient mice contain an alteration in one or both MCH1R alleles that substantially reduces expression of a functional MCH1R from the altered allele. The production of MCH1R deficient mice is illustrated by a viable MCH1R -/- knockout mouse where expression of MCH1R is eliminated from both MCH1R alleles. Based on the guidance provided herein concerning the production of such viable MCH1R -/- mice, MCH1R deficient mice containing different types of alterations in one or both MCH1R allele can be produced.

MCH1R deficient mice have a variety of uses such as being used as a tool to examine the physiological roles of MCH1R, to evaluate the ability of compounds to target MCH1R, and to evaluate the ability of compounds to compensate for a deficiency in MCH1R. The ability of compounds to target MCH1R or to compensate for a MCH1R deficiency can be evaluated by measuring changes in one or more phenotypes associated with a MCH1R deficiency.

Studies involving MCH1R mice are preferably performed using mice with an alteration in both MCH1R alleles. Mice containing an alteration in one allele are preferably used as an intermediate animal in the initial production of mice having alterations in both alleles. Propagation of mice with an alteration in both alleles is preferably achieved using male and female mice containing alterations in both MCH1R alleles.

Phenotypes observed in MCH1R deficient mice include reduced fat mass, increased food consumption when mice are maintained on regular chow, hyperactivity, neuroendocrine abnormalities, increased energy expenditure as

measured by indirect calorimetry, reduced respiratory quotient as measured by indirect calorimetry, decreased sensitivity to diet-induced obesity, resistance to the orexigenic effects of intracerebroventricular administration of MCH and resistance to the anorectic effects of intracerebroventricular administration of a peptide antagonist of MCH1R.

The observed phenotypes of MCH1R deficient mice point to additional phenotypes associated with energy metabolism alterations. Such additional phenotypes include one or more of the following: increased muscle mass; altered glucose or insulin tolerance, as for instance measured by an oral glucose tolerance test or an intraperitoneal insulin tolerance test; altered sensitivity to intracerebroventricularly administered peptide and non-peptide agonists and antagonists of MCH1R and of other energy expenditure pathways; and altered responsiveness to modulation of food intake pathways and pathways affecting other aspects of energy expenditure.

MCH1R deficient mice with different alterations can have varying degrees of phenotypes associated with a MCH1R $-/-$ knockout mouse. In different embodiments, using techniques described in the Examples below, mice with an MCH1R deficiency consume approximately 12% to approximately 16% more food than MCH1R wild-type mice, and MCH1R deficient mice have approximately a 2-fold increase in dark phase ambulatory activity compared to wild-type mice.

Production of MCH1R Deficient Mice

Based on the guidance provided herein, different types of MCH1R deficient mice can be produced. A preferred scheme for producing MCH1R deficient mice involves producing male and female mice with an altered MCH1R allele and breeding the mice to produce mice having alterations in both alleles.

Techniques for producing mice with an altered genome are well known in the art. (Ausubel, Chapter 23, Manipulating the Mouse Genome, *Current Protocols in Molecular Biology*, John Wiley, 2001). An example of a scheme for producing a mouse with an altered MCH1R allele involves the following:

- (a) altering the MCH1R allele in a mouse embryonic stem cell by homologous recombination with a transgene to produce an altered embryonic stem cell;
- (b) introducing the altered embryonic stem cell into a mouse blastocyst to produce an altered blastocyst;

- (c) introducing the altered blastocyst into a pseudopregnant mouse to produce a pregnant mouse;
- (d) allowing the pregnant mouse to produce offspring; and
- (e) screening the offspring for the presence of an altered MCH1R allele to identify a MCH1R deficient mouse.

Genetic elements involved in gene expression include transcription and translation elements such as a promoter, transcription factor binding sites, splicing sites, polyadenylation region, and ribosome binding site. Removing or altering these elements will decrease or eliminate the production of MCH1R from the MCH1R gene.

MCH1R structural gene alterations can be used to produce an MCH1R derivative having little or no MCH1R activity. A preferred alteration to the MCH1R structural gene involves deleting substantially all of the gene.

A deletion in an MCH1R allele can be accompanied by an insertion of additional nucleic acid. Additional nucleic acid that may be inserted includes nucleic acid encoding a selectable marker having an independent promoter and nucleic acid encoding a reporter protein transcriptionally coupled to the MCH1R promoter. Examples of reporter protein that can be used in chimeric mice are β -galactosidase (*lacZ*) and green fluorescent protein (GFP) and its derivatives.

Initial alterations are preferably produced using a transgene containing one or more selectable makers and nucleic acid targeting MCH1R for insertion by homologous recombination. Homologous recombination can be performed to create alterations in MCH1R and/or remove MCH1R regions. Markers can be used to facilitate screening for the insertion into a mouse genome, for the insertion occurring by homologous recombination (Ausubel, Chapter 23, *Manipulating the Mouse Genome*, *Current Protocols in Molecular Biology*, John Wiley, 2001), and for evaluating mRNA localization and expression.

A transgene used for homologous recombination may contain recombinase systems, which may be employed to excise inserted nucleic acid. Examples of recombinase systems include the bacteriophage recombinase Cre/*loxP* system and the yeast recombinase Flp/FRT system. (Ausubel, Chapter 23, *Manipulating the Mouse Genome*, *Current Protocols in Molecular Biology*, John Wiley, 2001, and U.S. Patent No. 5,564,182.) *loxP* recognition sites can be positioned 3' and 5' of a region to be removed and excised by Cre recombinase.

Similarly, *flp* recognition sites can be positioned 3' and 5' of a region to be removed and excised by Flp recombinase.

Screening for mice containing an altered MCH1R allele can be achieved using techniques such as those measuring the production of MCH1R mRNA transcripts and whether any produced MCH1R transcript is different from wild-type transcript. Techniques for measuring MCH1R mRNA transcripts and the type of transcript include nucleic acid hybridization analysis such as a northern blot analysis which can detect the production and size of transcripts with the use of smaller nucleic acid probes specific for a particular sequence. Polymerase chain reaction (PCR) or *in situ* hybridization can also be employed to measure MCH1R mRNA transcripts.

Whether or not a particular alteration substantially reduces expression of a functional MCH1R can be determined by producing mice containing such alterations in both alleles. The phenotype of mice containing the alteration in both alleles is determined by comparing the phenotypes of MCH1R *-/-* knockout mice and MCH1R wild-type mice.

Assays Involving MCH1R Mice

Assays involving MCH1R deficient mice can be performed to measure the effect of a compound on a MCH1R deficiency. Such assays can be performed for different purposes such as evaluating the ability of a compound to compensate for a MCH1R deficiency and evaluating the ability of a compound to selectively act at MCH1R.

The effect of a compound on MCH1R deficiency *in vivo* can be evaluated by measuring one or more phenotypes associated with MCH1R. Techniques for measuring different activities such as food consumption, body weight, stress, anxiety, locomotor activity, sleep, fatigue, circadian rhythm, and energy metabolism are well known in the art. (See, for example, Crawley, J.N., What's Wrong with My Mouse, Wiley-Liss, 2000, Chen, *et al.*, 2000. *Trans. Res.* 9, 145-154 and Chen, *et al.*, 2000. *Nat. Genetics* 26, 97-102.) Examples of techniques for measuring some these different activities are described in the Examples provided below.

In different embodiments, compounds administered to MCH1R deficient mice have previously been identified as MCH1R or MCH2R active compounds using an *in vitro* assay. MCH2R is another receptor that binds MCH.

MCH1R and MCH2R active compounds modulate activity of either or both MCH1R and MCH2R, and include agonists, antagonists, and allosteric modulators.

The ability of a compound to affect *in vitro* MCH1R or MCH2R activity can be determined using a cloned receptor and measuring receptor activity.

- 5 The amino acid and encoding cDNA sequences for human MCH1R and MCH2R are provided by SEQ. ID. NOs. 1-4. SEQ. ID. NOs. 1 and 2 provide the amino acid and encoding cDNA for human MCH1R. SEQ. ID. NOs. 3 and 4 provide the amino acid and encoding cDNA for human MCH2R.

- 10 MCH1R and MCH2R are G protein coupled receptors. MCH1R couples to both Gi and Gq, while MCH2R couples to Gq. Coupling of Gi results in the inhibition of adenylate cyclase and subsequent reductions in cAMP levels. Coupling to Gq leads to activation of phospholipase C and subsequent elevation of intracellular Ca^{2+} .

- 15 Recombinantly expressed receptor can be used to facilitate determining whether a compound is active at that receptor. For example, MCH1R or MCH2R can be expressed by an expression vector in a cell line such as HEK 293, COS 7, and CHO not normally expressing the receptor, where the same cell line without the expression vector or with an expression vector not encoding the receptor can act as a control.

- 20 Techniques for measuring different G-protein activities, such as Gi, Gs, and Gq are well known in the art. Gi and Gs activity can be measured using techniques such as a melonaphore assay, assays measuring cAMP production, assays measuring inhibition of cAMP accumulation, and assays measuring binding of ^{35}S -GTP. cAMP can be measured using different techniques such as a radioimmunoassay and indirectly by cAMP responsive gene reporter proteins.

- 25 Gq activity can be measured using techniques such as those measuring intracellular Ca^{2+} . Examples of techniques well known in the art that can be employed to measure Ca^{2+} include the use of dyes such as Fura-2 and the use of Ca^{2+} -bioluminescent sensitive reporter proteins such as aequorin. An example of a cell line employing aequorin to measure G-protein activity is HEK293/aeq17. (Button, *et al.*, 1993. *Cell Calcium* 14, 663-671, and Feighner, *et al.*, 1999. *Science* 284, 2184-2188.)

30 Compounds modulating MCH1R activity include agonists, antagonists and allosteric modulators. The ability of a test compound to antagonize MCH1R can

be measured by activating the receptor using an MCH1R agonist and measuring the effect of the test compound on MCH1R activity.

- MCH1R and MCH2R active compounds have therapeutic applications. Such applications include the ability to achieve one or more of the following: weight loss (*e.g.*, treat obesity), weight gain, treat cancer (*e.g.*, colon or breast), reduce pain, treat diabetes, reduce stress and anxiety, treat locomotor deficits, treat sexual dysfunction, treat fatigue, or treat sleep disorders.

Additional Assays

- 10 The increased locomotor activity of MCH1R deficient mice points to associations between MCH1R and stress, anxiety, fatigue, circadian rhythm, and sleep. Compounds affecting stress, anxiety, fatigue, circadian rhythm, or sleep, can be identified using an *in vitro* MCH1R assay followed by an *in vivo* assay. The *in vivo* assay is performed in a mammal such as a mouse, rat, dog, ferret or monkey.
- 15 Compounds affecting locomotor activity, stress, anxiety, fatigue, circadian rhythm, or sleep can be used as a research tool and to achieve useful effects in a patient. Useful effects include reducing stress, anxiety or fatigue, and altering sleep patterns. Alteration of sleep patterns is useful to, for example, treat sleep disorders and treat jet lag. Preferably, the patient is human patient.
- 20 In different embodiments, the ability of a MCH1R active compound that increases MCH1R activity is tested in an *in vivo* assay that measures a decrease in stress, anxiety or locomotor activity; the ability of a MCH1R active compound that decreases MCH1R activity is tested in an *in vivo* assay that measures a reduction in fatigue and the ability of a compound to modulate MCH1R activity is tested in an *in vivo* assay
- 25 that measures alterations in circadian rhythm or sleep.

EXAMPLES

- Examples are provided below to further illustrate different features of the present invention. The examples also illustrate useful methodology for practicing the invention. These examples do not limit the claimed invention.

Example 1: Generation of MCH1R $-/-$ Mice

- MCH1R $-/-$ mice were produced using recombinant techniques to obtain MCH1R $+/-$ mice and breeding the MCH1R $+/-$ mice. Production of MCH1R $+/-$ mice involved using an MCH1R targeting vector to disrupt the MCH1R allele in

embryonic stem (ES) cells, injecting the transformed ES cells into a blastocyst, implanting the blastocyst into a pseudopregnant female, and identifying MCH1R +/- offspring.

5 A 14 Kb mouse genomic clone containing MCH1R was obtained from a mouse 129SvJ lambda genomic library (Lambda FIX II Library, Stratagene, La Jolla, CA). The clone was identified by screening the library with a 500 bp mouse MCH1R cDNA probe generated from MCH1R by PCR using primers derived from the rat MCH1R sequence. The rat MCH1R sequence is described as the rat SLC-1 in Lakaye, *et al.*, 1988. *Biochim. Biophys. ACTA* 1401:216-220.

10 The MCH1R targeting vector was made up of two homologous recombination targeting regions, a positive selection element, and a negative selection element (Figure 1). The two homologous recombination targeting regions were obtained from the mouse genomic clone. One of the regions was a 6.5 Kb 5' MCH1R KpnI to KpnI fragment. The second region was an 1.4 kb 3' MCH1R BamHI to XbaI
15 fragment.

PGKneo was used as the positive selection element and HSV-thymidine kinase was used as the negative selection element. PGKneo provides for neomycin resistance, which serves as a positive selection for integration into the mouse genome. HSV-thymidine kinase provides for sensitivity to acyclovir and its
20 analogs, providing for a negative selection against integration not involving homologous recombination.

Homologous recombination of the targeting vector into the mouse genome was performed by linearizing the targeting vector with NotI and transforming AB2.2 ES cells by electroporation. Electroporation was performed with 1×10^7
25 AB2.2 ES cells and 25 μ g of vector under standard conditions using a BioRad Gene Pulser (Instruction manual, Lexicon Genetics, The Woodlands, Texas 77381, Catalog number K100). Transfected cells were then cultured with G418/FIAU for positive and negative selections, respectively. FIAU is the uracil derivative; 2'-fluoro-2'-deoxy-1beta-D-arabinofuranosyl-5-iodo-uracil. Approximately 500 neomycin
30 resistant clones were selected and Southern blot analysis revealed ten correctly targeted ES cell clones in which one of the two MCH1R alleles was successfully replaced by the PGK-neomycin resistance cassette.

The ten ES cell clones were expanded and microinjected into mouse blastocysts. Mouse blastocysts were implanted into a pseudopregnant female mice.
35 (Gene Targeting, a practical approach, Joyner A.L. eds, IRL press, 1993.) The

implanted mice were allowed to go to term. Transgenic MCH1R +/- offspring were identified by Southern analyses.

Transgenic MCH1R -/- mice were produced by breeding male and female MCH1R +/- mice. MCH1R -/- mice were produced in the expected Mendelian ratio. The absence of MCH1R alleles was verified by Southern blot and PCR genotyping. MCH1R -/- mice of both sexes are fertile and their growth rates are comparable to that of wild-type littermate controls out to approximately 20 weeks of age. MCH1R -/- mice greater than approximately 20 weeks of age exhibit slightly, but significantly, lower body weights as compared to wild-type littermate mice.

PCR genotyping was performed using a Qiagen HotStart PCR kit following the Qiagen protocol. Three different oligonucleotide primers were used to distinguish the knockout allele from the wild-type allele.

MCH-5L2 (SEQ. ID. NO. 5): 5'- AAA TTG CTA GGG AGG CTT GCA G - 3';
 neo-5 (SEQ. ID. NO. 6): 5'- TAA AGC GCA TGC TCC AGA CTG CCT T - 3';
 MCH-3t (SEQ. ID. NO. 7): 5'- TTA AAG GAA CCC AAG CTA GGC ACC - 3'.
 Primer pair MCH-5L2 and MCH-3t generates a 190 bp fragment from the wild-type MCH1R allele, while primer pair neo-5 and MCH-3t generates a 260 bp fragment from the disrupted MCH1R allele.

Southern blot analysis was performed using a 3' probe and a coding region probe. (Sambrook, *et al.*, Molecular Cloning, a Laboratory Manual, 2nd ed. 1989). The 3' flanking probe is a 0.95 kb PCR fragment located 180 bp 3' of the short arm of the targeting vector. Upon EcoRV-HpaI digestion, the probe detects a 6.0 kb band from the wild-type MCH1R allele, and a 4.2 kb band from the mutant allele (Figure 1).

The coding region probe is a 1.1 kb Kpn-BamHI fragment covering a portion of the MCH1R coding region, including the first transmembrane domain to the stop codon. The coding region probe also detects a 6.0 kb wild-type band on EcoRV-HpaI digested genomic DNA, but detects no signal from the knocked out allele.

Mouse cDNA encoding for MCH1R and the mouse MCH1R sequences are provided by SEQ. ID. NOs. 10 and 11. SEQ. ID. NO. 10 provides the cDNA sequence. SEQ. ID. NO. 11 provides the amino acid sequence.

Example 2: In Situ Hybridization

In situ hybridization was performed to verify the absence of MCH1R mRNA in the brain of MCH1R $-/-$ mice. MCH1R $-/-$ and age/sex matched wild-type control mice were killed by decapitation, and brains were quickly removed and frozen in -40°C isopentane, and stored at -80°C until use. Coronal brain sections ($14\ \mu\text{M}$) were cut at -17°C with a cryostat microtome and thaw-mounted onto baked microslides. Following fixation in ice-cold 4% phosphate-buffered paraformaldehyde, the tissue sections were stored in 95% ethanol at 4°C until use.

Hybridization was performed using hybridization probes that consist of an equal molar mixture of two non-overlapping, antisense oligonucleotides against the coding region of MCH1R:

Oligo 407 (SEQ. ID. NO. 8):

5'-CTAATGAACGAGAGAGCCACAGGAGGCAGATCACCAGGGTGGCC-3'

Oligo 408 (SEQ. ID. NO. 9):

5'-CCAGCACACAAAGAAGACCAGACAGATGGCAATGGCTGTGCGGGT-3'

The probes were terminally labeled with $[\alpha\text{-}^{33}\text{P}]\text{dATP}$ and terminal transferase, and hybridization and washing conditions were as described in Guan, *et al.*, 1998. *Mol. Brain Res.* 59, 273-279. mRNA transcripts were observed in wild-type mice, but not in MCH1R $-/-$ mice.

Example 3: Evaluation of Body Composition

Evaluations of body composition were performed using 5-7-month-old male and female MCH1R $+/+$, MCH1R $+/-$, and MCH1R $-/-$ littermate mice. Body composition was analyzed by dual energy x-ray absorptiometry (DEXA; QDR 4500, Hologic, Inc.), using the QDR 4500 Small Animal Studies software version 9.0.

DEXA revealed that both male and female 5-7-month-old MCH1R $-/-$ mice were significantly leaner than wild-types (Figure 2). Both genders of MCH1R $-/-$ mice possessed ~50 % less fat mass and ~7 % more lean mass than wild-types. Male and female MCH1R $+/-$ mice exhibited normal body composition. Evaluation of a subset of individual fat pads and DEXA analysis of individually-housed animals from the second line corroborated the lean phenotype.

Example 4: Food Intake Measurement

Food intake measurements were performed using male and female MCH1R +/+, MCH1R +/-, and MCH1R -/- mice. The mice were separated into individual microisolator cages at approximately one month of age and at least seven days prior to the initiation of any experiment.

Regular mouse chow (Teklad 7012; 5% fat, 19% protein, and 5% fiber; 3.41 grams/kcal and 14.8% kcal from fat) was provided to 9.5-10-week-old mice as pellet food in wire cage tops containing food hoppers. Food was weighed daily for 4 days. Food intake reported as the average food consumed per mouse per day over the course of the four-day period is shown in Table 1.

Table 1. Daily Food Consumption of Male and Female MCH1R Mice

Gender and Genotype	Daily Food Consumption (g/mouse/day) Mean \pm SEM	n value	P value
Male MCH1R+/+	4.18 \pm 0.14	11	
Male MCH1R+/-	4.26 \pm 0.12	10	
Male MCH1R-/-	4.84 \pm 0.18 [#]	11	*, < 0.02 vs. +/+; [#] , < 0.02 vs. +/-
Female MCH1R+/+	4.06 \pm 0.16	10	
Female MCH1R+/-	3.70 \pm 0.44*	4	
Female MCH1R-/-	4.56 \pm 0.15 [#]	8	*, < 0.04 vs. +/+; [#] , < 0.04 vs. +/-

Both male and female MCH1R -/- mice are significantly hyperphagic. Male and female MCH1R -/- mice consumed approximately 16% and 12% more food, respectively, than wild-type control mice.

Example 5: Assessment of Ambulatory Activity and Fine Movements

Ambulatory activity and fine movement studies were performed using MCH1R +/+, MCH1R +/- and MCH1R -/- mice. The locomotor activity of male MCH1R +/+, MCH1R +/-, and MCH1R -/-, and female MCH1R +/+, MCH1R +/- and MCH1R -/- 8-9-week-old littermate mice was examined using a cage rack Photobeam Activity System (San Diego Instruments). Mice were housed individually in transparent plexiglass cages (40 x 20 x 20 cm) for several weeks prior to evaluation.

The results of the ambulatory activity and fine movement studies are shown in Tables 2 and 3. During examination two consecutive photobeam breaks occurring in adjacent photobeams was scored as ambulatory movement. Two or more

- consecutive photobeam breaks occurring in the same photobeam, with no other photobeams being interrupted, was scored as fine movements. The total number of ambulatory movements in a given part of the light cycle multiplied by the distance between two adjacent photobeams (0.053975 m) equaled the total distance traveled during that given part of the light cycle. MCH1R ^{-/-} mice of both sexes exhibit approximately a 2-fold increase in dark phase ambulatory activity.

Table 2. Ambulatory Activity of Male and Female MCH1R Mice

Gender and Genotype	Ambulatory Activity (meters traveled) Mean \pm SEM		N value	P value	
	Light phase	Dark phase		Light phase	Dark phase
Male MCH1R+/+	31.20 \pm 6.49	114.35 \pm 16.38	11		
Male MCH1R+/-	19.19 \pm 4.61	98.73 \pm 7.26	6		
Male MCH1R-/-	49.74 \pm 6.09 ^{*#}	223.70 \pm 29.32 ^{*#}	11	[*] , = 0.05 vs. +/+; [#] , <0.004 vs. +/-	[*] , <0.005 vs. +/+; [#] , <0.008 vs. +/-
Female MCH1R+/+	29.39 \pm 6.37	105.52 \pm 11.93	10		
Female MCH1R +/-	64.03 \pm 21.14	100.23 \pm 17.30	4		
Female MCH1R-/-	57.55 \pm 13.41 [*]	209.81 \pm 19.64 ^{*#}	8	[*] , = 0.06 vs. +/+	[*] , <0.001 vs. +/+; [#] , <0.006 vs. +/-

10

Table 3. Fine Movements of Male and Female MCH1R Mice

Gender and Genotype	Fine Movements (number of beam breaks) Mean \pm SEM		N value	P value	
	Light phase	Dark phase		Light phase	Dark phase
Male MCH1R+/+	707.18 \pm 124.07	1619.84 \pm 243.26	11		
Male MCH1R+/-	865.50 \pm 58.70	1703.33 \pm 108.86	6		
Male MCH1R-/-	889.36 \pm 122.11	2672.54 \pm 270.36 ^{*#}	11		[*] , <0.01 vs. +/+; [#] , <0.03 vs. +/-
Female MCH1R+/+	1034.4 \pm 121.27	1969.25 \pm 89.01	10		
Female MCH1R +/-	1209.25 \pm 234.84	2098.75 \pm 472.62	4		
Female MCH1R-/-	1178.75 \pm 163.29	2429.00 \pm 88.16 [*]	8		[*] , <0.005 vs. +/+

Example 6: Assessment of Metabolic Rate and Respiratory Quotient

Metabolic rate and respiratory quotient were evaluated by indirect calorimetry using MCH1R $+/+$ and MCH $-/-$ mice. The locomotor activity of male MCH1R $+/+$ and MCH1R $-/-$ 12-week-old littermate mice was examined using a 16-chamber open-circuit Oxymax system (Columbus Instruments). Mice were housed individually in transparent plexiglass cages (40 x 20 x 20 cm) for several weeks prior to evaluation.

MCH1R $-/-$ mice exhibited a significantly greater metabolic rate during a portion of the dark phase of the light-dark cycle (Figure 3) that was temporally correlated with the period of hyperactivity, suggesting that this increase in metabolic rate is secondary to the hyperactivity. The respiratory quotient, an indicator of metabolic fuel preference, was significantly lower in male MCH1R $-/-$ mice during the light phase, but was indistinguishable from that of wild-types during the dark phase (Figure 4), implying that MCH1R $-/-$ mice rely upon the oxidation of free fatty acids and less upon glycolysis during periods when they are not actively eating.

Example 7: Assessment of Neuroendocrine Profile

Neuroendocrine profiles were evaluated in male and female MCH1R $+/+$ and MCH $-/-$ littermate mice. Plasma leptin, insulin, total T4 and corticosterone levels were measured by RIA. Plasma glucose and triglyceride levels were measured by enzyme-colorimetric assays (Sigma and Roche, respectively).

Plasma glucose, insulin and triglyceride levels were not significantly different in 5-7-month-old MCH1R $-/-$ and wild-type littermates of either gender (Table 4). Plasma leptin and total thyroxine (T4) levels were significantly lower in male *Mchl $r^{-/-}$* mice relative to wild-types, and female levels revealed similar trends (Table 4). Lower leptin levels are consistent with the lean phenotype and lower T4 levels support the notion that MCH may be involved in the regulation of thyroid function (Kennedy, *et al.*, 2000. *Endocrinology* 142:3265-3268). Alternatively, alterations in T4 levels may reflect a compensatory response to the increased energy expenditure. Plasma corticosterone levels were significantly greater in 6-7-month-old male *Mchl $r^{-/-}$* mice relative to wild-type littermates (Table 4). This is consistent with the finding that MCH administration reduces basal and stress-induced plasma ACTH levels in rats (Bluet-Pajot, *et al.*, 1995. *J. Neuroendocrinol.* 7:297-303), and suggests that MCH1R may be involved in the regulation of adrenal function.

Table 4. Neuroendocrine Profiles of Male and Female MCH1R Mice.

	Males		Females	
	MCH1R +/+	MCH1R -/-	MCH1R +/+	MCH1R -/-
Leptin (ng/ml)	6.05 ± 1.99	2.12 ± 0.08*	3.87 ± 0.92	2.31 ± 0.06
Triglyceride (mg/dl)	77 ± 10	69 ± 6	57 ± 7	64 ± 5
Insulin (ng/ml)	0.61 ± 0.15	0.57 ± 0.12	0.31 ± 0.04	0.33 ± 0.04
Glucose (mg/dl)	140 ± 7	137 ± 5	132 ± 5	123 ± 4
T4 (µg/dl)	5.35 ± 0.25	4.32 ± 0.23*	4.58 ± 0.37	4.05 ± 0.22
Corticosterone (ng/ml)	9 ± 1.1	23.6 ± 5.4*	ND	ND

5 Plasma leptin, triglyceride, insulin, glucose and total thyroxine (T4) levels of group-housed male and female 5-7-month-old MCH1R littermate mice (n = 10-14 per group). Plasma corticosterone levels of individually-housed 6-7-month-old male MCH1R littermate mice (n = 9-10 per genotype) maintained in isolation and fed *ad libitum*. * $P \leq 0.05$; ND, not determined.

Example 8: Assessment of Neuropeptide Expression.

10 Corticotrophin-releasing factor (CRF) mRNA levels in the brain were measured by *in situ* hybridization. CRF mRNA levels in the paraventricular nucleus of the hypothalamus (PVN) were significantly lower in male MCH1R -/- mice relative to wild-types, yet were normal in the central nucleus of the amygdala (CEA) (PVN: MCH1R -/-, 79.5 ± 9.6 Ci/g tissue; MCH1R +/+, 105.3 ± 10.1 Ci/g tissue; $P < 0.05$;
15 CEA: MCH1R -/-, 57.5 ± 1.3 Ci/g tissue; MCH1R +/+, 57.0 ± 5.9 Ci/g tissue; n = 5 per genotype). This suggests that the elevated corticosterone levels are not due to increased hypothalamic CRF. Instead, it is likely that the reduced CRF expression in the PVN is a consequence of negative feedback driven by the elevated levels of corticosterone. In contrast to CRF, hypothalamic levels of neuropeptide Y (NPY),
20 agouti-related protein (AgRP), galanin, pro-opiomelanocortin, and cocaine- and amphetamine-regulated transcript mRNAs measured during the light phase were all normal in MCH1R -/- mice.

Example 9: Assessment of Responsiveness to Diet-induced Obesity.

Female wild-type mice maintained on a high fat diet for seven weeks gained significantly more body weight than wild-type littermates maintained on regular chow (Figure 5). In contrast, female MCH1R $-/-$ mice maintained on the high fat diet gained the same amount of body weight as MCH1R $-/-$ littermates maintained on regular chow. This decreased susceptibility to diet-induced obesity is most likely a consequence of the hyperactivity and associated increase in energy expenditure. Interestingly, maintenance on the high fat diet abolished the significant hyperphagia (24.3 %) observed with maintenance on regular chow (Figure 6).

10

Example 10: Assessment of Responsiveness to Centrally Administered Orexigenics.

MCH1R $-/-$ mice exhibited normal responses to both acute left lateral and dorsal third ventricle administrations of NPY and AgRP, demonstrating that MCH1R is not required for their orexigenic actions. Additionally, these data suggest that the hyperphagia is not a consequence of heightened NPY or AgRP signaling. Acute administrations of MCH were without significant effects, but tended to increase the food intake of only wild-types. Subsequently, the responses of MCH1R $-/-$ and wild-type littermates to chronic dorsal third ventricle infusions of MCH were evaluated. Six days of chronic MCH treatment resulted in significantly greater food intake (Figure 7), body weight gains (Figure 8) and altered body composition (Figure 9) in wild-types, while MCH1R $-/-$ littermates were not affected, demonstrating that MCH1R is required for the orexigenic actions of MCH.

Other embodiments are within the following claims. While several embodiments have been shown and described, various modifications may be made without departing from the spirit and scope of the present invention.

WHAT IS CLAIMED IS:

1. A melanin concentrating hormone type 1 receptor (MCH1R) deficient mouse whose genome comprises an alteration in one or both MCH1R alleles, wherein said alteration substantially reduces expression of a functional MCH1R.
5
2. The mouse of claim 1, wherein said mouse comprises said alteration in one allele and said alteration comprises a transgene insertion eliminating expression of functional MCH1R.
10
3. The mouse of claim 1, wherein said mouse comprises said alteration in both alleles, and said alteration comprises a transgene insertion eliminating expression of functional MCH1R.
15
4. The mouse of claim 1, wherein said mouse comprises said alteration in one allele and said alteration comprises the complete removal of MCH1R encoding nucleic acid.
5. The mouse of claim 1, wherein said mouse comprises said alteration in both alleles and said alteration comprises the complete removal of MCH1R encoding nucleic acid.
20
6. A method of producing a MCH1R deficient mouse comprising an alteration of the MCH1R gene in an MCH1R allele comprising the steps of:
25
 - (a) altering said MCH1R allele in a mouse embryonic stem cell by homologous recombination with a transgene to produce an altered embryonic stem cell;
 - (b) introducing said altered embryonic stem cell into a mouse blastocyst to produce an altered blastocyst;
30
 - (c) introducing said altered blastocyst into a pseudopregnant mouse to produce a pregnant mouse;
 - (d) allowing said pregnant mouse to produce offspring; and
 - (e) screening said offspring for the presence of an altered MCH1R allele to identify said MCH1R deficient mouse.
35

7. The method of claim 6, wherein said altering eliminates expression of functional MCH1R.

5 8. A method of producing a MCH1R deficient mouse comprising an altered MCH1R in both alleles comprising the steps of:

(a) breeding two mice each comprising an alteration of the MCH1R in one allele to produce offspring; and

10 (b) screening said offspring for the presence of said altered MCH1R in both alleles to identify said MCH1R deficient mouse.

9. The method claim 8, wherein said alteration comprises a transgene insertion eliminating expression of functional MCH1R.

15 10. The mouse of claim 8, wherein alteration comprises the complete removal of MCH1R encoding nucleic acid.

11. A method of measuring the affect of a compound on a MCH1R deficiency comprising the steps of providing said compound to the MCH1R mouse of any one of claims 1-5, and measuring one or more phenotypes associated with MCH1R activity.

12. The method of claim 11, wherein said phenotype is hyperphagic or hypophagic activity.

25 13. The method of claim 11, wherein said phenotype is a change in fat mass.

14. The method of claim 11, wherein said phenotype is a change in muscle mass.

15. The method of claim 11, wherein said phenotype is increased or decreased locomotor activity.

16. The method of claim 11, wherein said phenotype is increased or decreased fine motor movements.

17. The method of claim 11, wherein said phenotype is an increased or decreased metabolic indicator selected from the group consisting of: oxygen consumption, carbon dioxide production, metabolic rate, pseudo-resting metabolic rate, respiratory exchange ratio and respiratory quotient.

18. The method of claim 11, wherein said compound is active at MCH2R.

19. A method of screening for a compound affecting stress, anxiety, fatigue, locomotor activity, circadian rhythm, or sleep comprising the steps of:

- (a) identifying an MCH1R active compound able to modulate MCH1R activity using an *in vitro* assay; and
- (b) measuring the ability of said MCH1R active compound on stress, anxiety, fatigue, locomotor activity, circadian rhythm, or sleep using an *in vivo* assay.

20. The method of claim 19, wherein said method is performed to screen for a compound to affect stress or anxiety, said MCH1R active compound identified in said step (a) causes an increase in MCH1R activity and said *in vivo* assay employed in said step (b) measures the ability of said MCH1R active compound to decrease stress or anxiety.

21. The method of claim 20, wherein said method is performed to screen for a compound to affect fatigue, said MCH1R active compound identified in said step (a) causes a decrease in MCH1R activity and said *in vivo* assay employed in said step (b) measures the ability of said MCH1R active compound to affect fatigue.

22. The method of claim 20, wherein said method is performed to screen for a compound to affect circadian rhythm and said *in vivo* assay employed in said step (b) measures the ability of said MCH1R active compound to affect circadian rhythm.

23. The method of claim 20, wherein said method is performed to screen for a compound to affect sleep and said *in vivo* assay employed in said step (b) measures the ability of said MCH1R active compound to affect sleep.

5

24. The method of claim 20, wherein said method is performed to screen for a compound to affect locomotor activity and said *in vivo* assay employed in said step (b) measures the ability of said MCH1R active compound to affect locomotor activity.

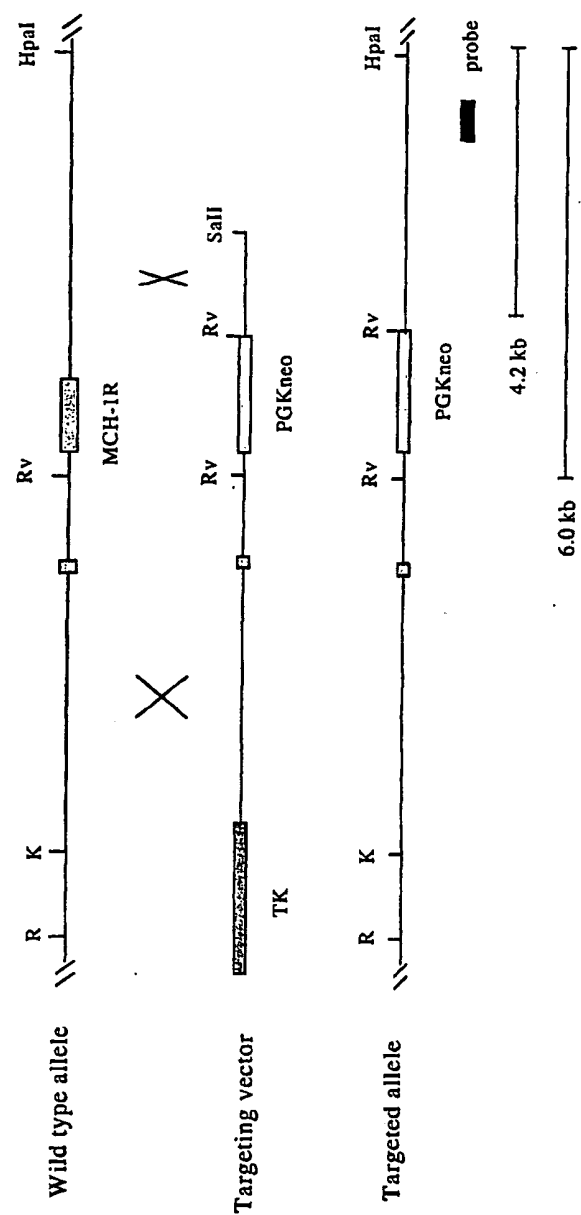


Fig. 1

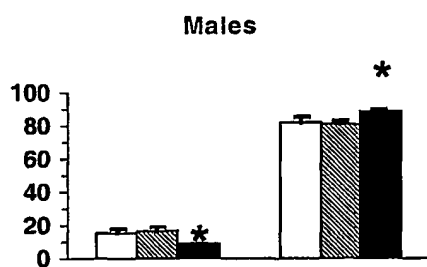


Fig. 2A

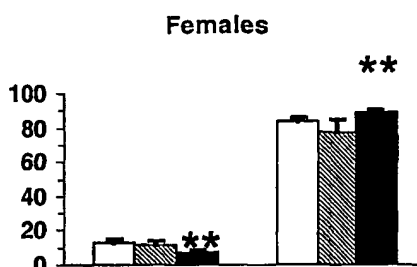


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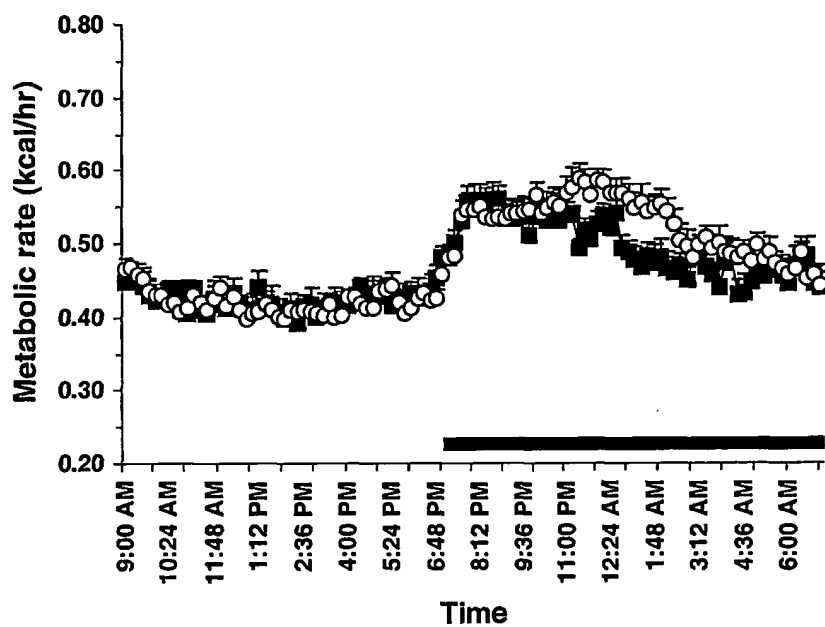


Fig. 3

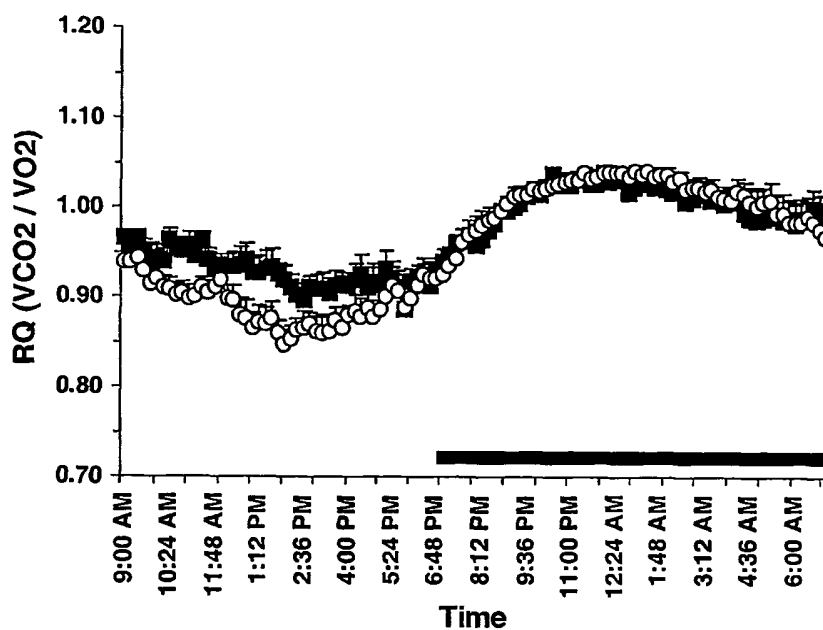


Fig. 4

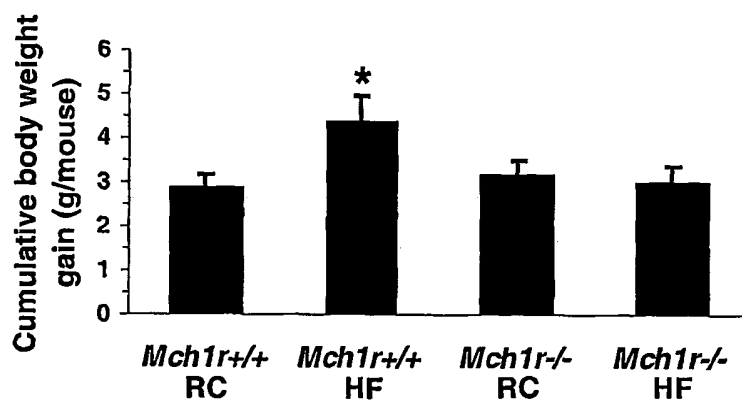


Fig. 5

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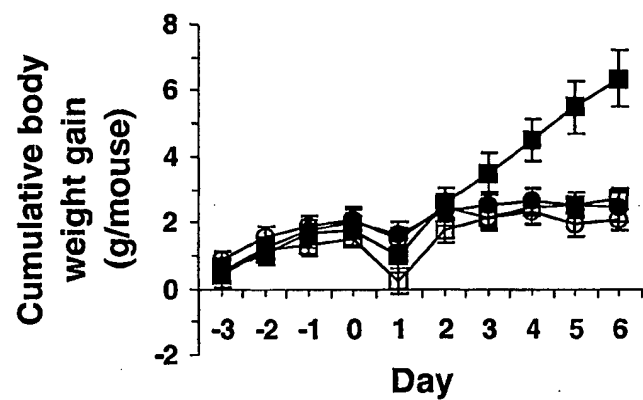


Fig. 8

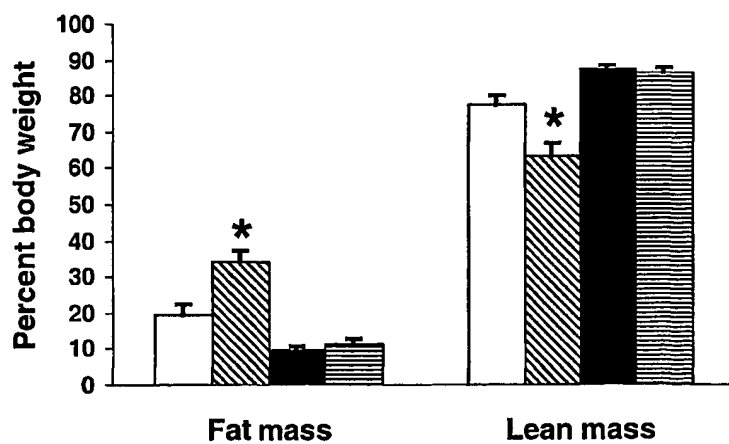


Fig. 9

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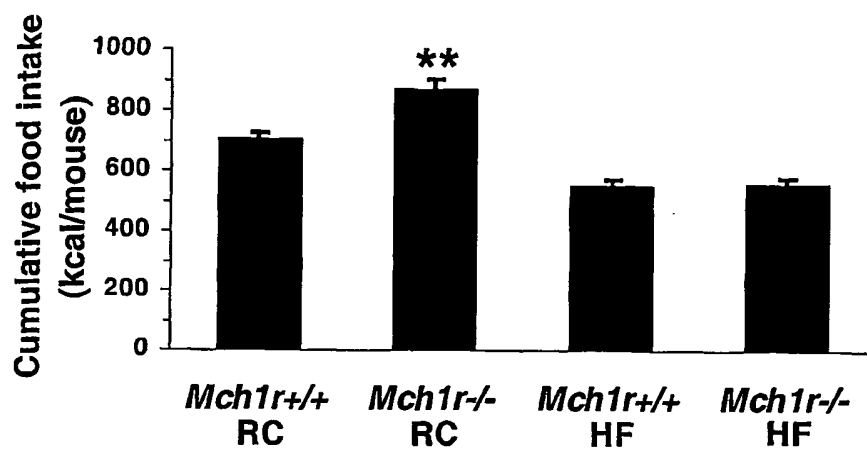


Fig. 6

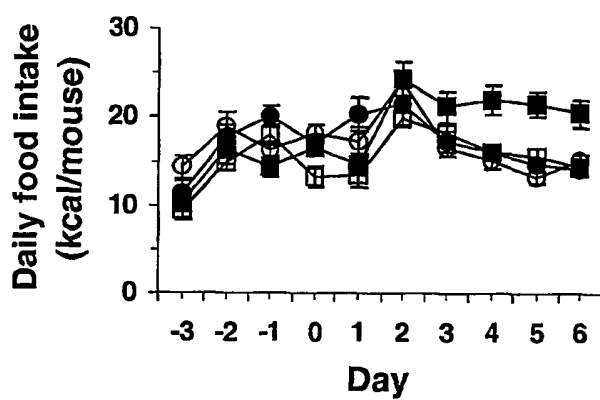


Fig. 7

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(54) Title: MCH1R DEFICIENT MICE

(57) Abstract: The present invention features viable MCH1R deficient mice. MCH1R deficient mice contain an alteration in one or both MCH1R alleles that substantially reduces expression of a functional MCH1R from the altered allele. Preferably, MCH1R deficient mice are MCH1R ^{-/-} knockout mice.

WO 02/077168 A3

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US02/08413

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : C12P 21/00

US CL : 800/4

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 800/4

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
US provisional 60/278,061Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EAST, STN(medline, biosis, embase, caplus)**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6,221,616 B1 (SALON ET AL) 24 April 2001 (24.04.2001), columns 17-18, starting on line 13.	1-24
X	US 6,221,613 B1 (SALON ET AL) 24 April 2001 (24.04.2001), columns 17-18, starting on line 13.	1-24
X, E	US 6,291,195 B1 (SALON ET AL), 18 September 2001 (18.09.2001), columns 17-18, starting at line 13.	1-24
Y	CHAMBERS ET AL. Melanin-concentrating hormone is the cognate ligand for the orphan G-protein-coupled receptor SLC-1. Nature. 15 July 1999, Vol. 400, pages 261-265, see entire reference.	1-24
Y	MACDONALD ET AL. Molecular characterization of the melanin-concentrating hormone/receptor complex: Identification of critical residues involved in binding and activation. Molecular Pharmacology. 2000, Vol. 58, pages 217-225, see entire reference.	1-24
Y	NOTHACKER ET AL. Identification of the natural ligand of an orphan G-protein-coupled receptor involved in the regulation of vasoconstriction. Nature Cell Biology. October 1999, Vol. 1, pages 383-385, see entire reference.	1-24

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C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DROZDZ ET AL. Characterization of the receptor for melanin-concentrating hormone on melanoma cells by photocrosslinking. Annals New York Academy of Sciences. 1999, pages 210-213.	1-24

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